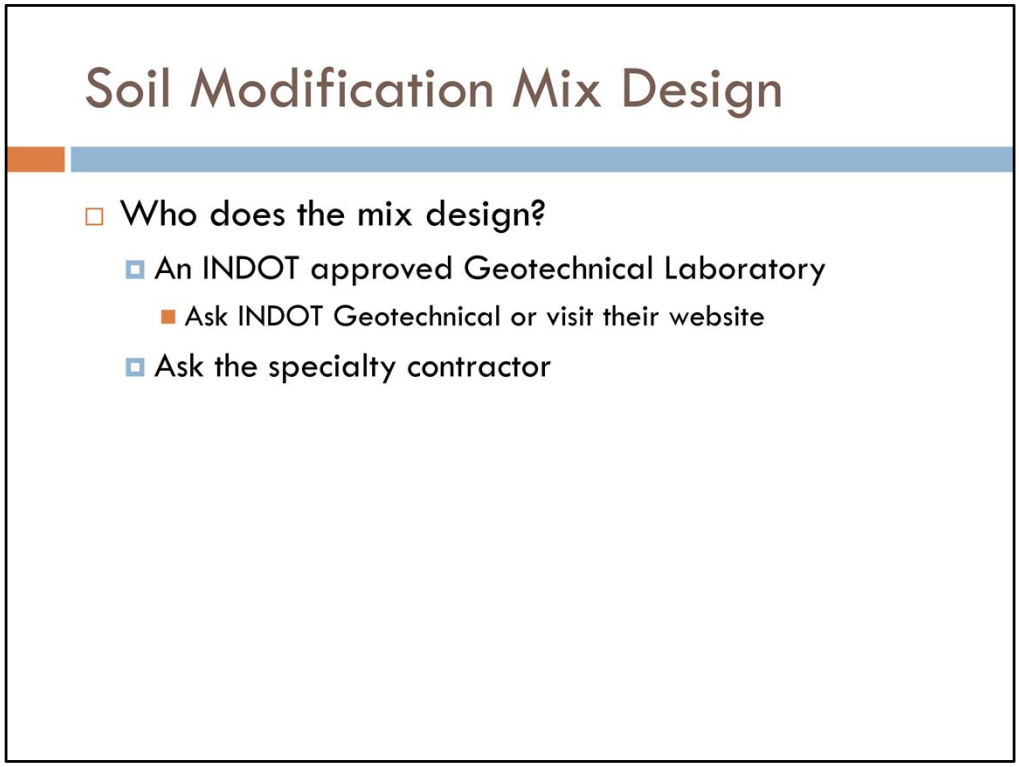
Soil Modification Mix Design

An Overview of Sample Acquisition and Laboratory Testing

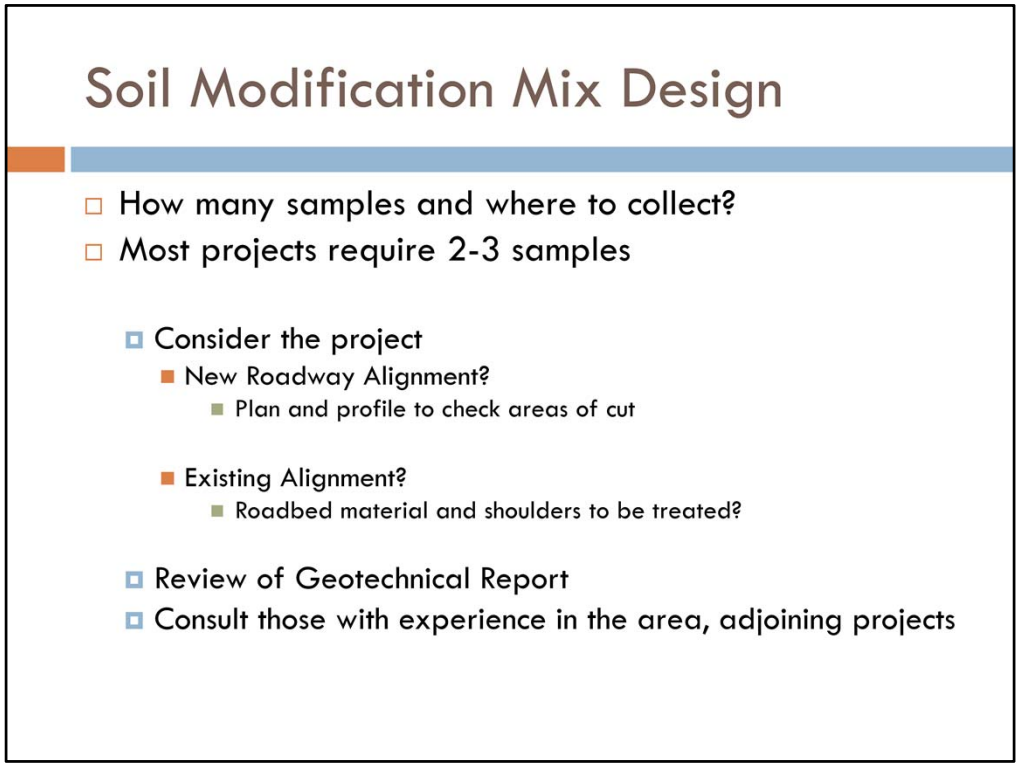
By: David Harness, P.E.
Alt & Witzig Engineering

Soil Modification Mix Design

- Typical questions:
  - Who does this work?
  - What about sampling?
  - What laboratory tests will be conducted?
  - What will the design tell me?
  - **How long will it take?**



Most often the specialty contractor would include the mix design portion of the project in their costs. Most times they will contact the consultant.



Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that "as received" moisture content can be determined.

Soil Modification Mix Design

- INDOT requires that the laboratory send a representative to collect the soil samples.
- How do we collect samples?

Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that "as received" moisture content can be determined.

Soil Modification Mix Design

- Existing Roadway?

Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that “as received” moisture content can be determined.

Soil Modification Mix Design

- Exposed soil near or at subgrade elevation?

Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that “as received” moisture content can be determined.

Soil Modification Mix Design

- Deeper samples or hard digging?

Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that “as received” moisture content can be determined.

Soil Modification Mix Design

- How much soil?

Typically 2-3 samples are collected. Larger jobs may have many samples over the length of the project. Collect 50-75 pounds per sample. Label with contract number, station & offset. Close or cover sample so that “as received” moisture content can be determined.

Soil Modification Mix Design

- What laboratory tests will be conducted?
  - Grainsize Analysis
    - Hydrometers and Sieves
  - Atterberg Limits
  - pH, Soluble Sulfates, Moisture Content
  - Moisture-Density Relationship (Proctor)
  - In some cases: LOI, Marl, Eades & Grim

Chemical Modification Flow Chart

Appendix 1

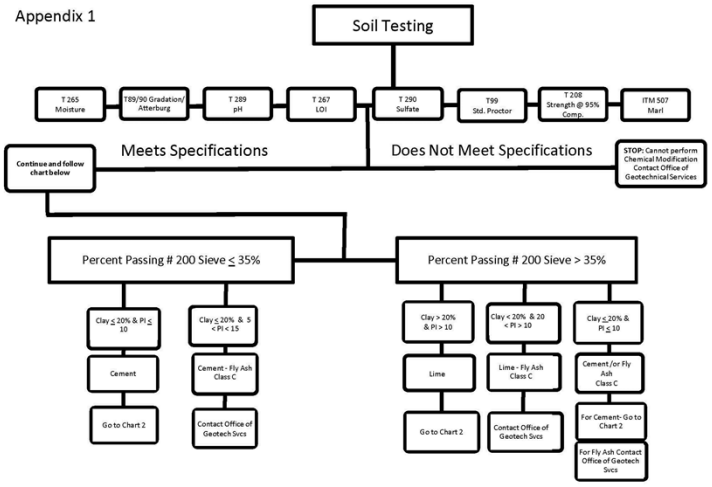
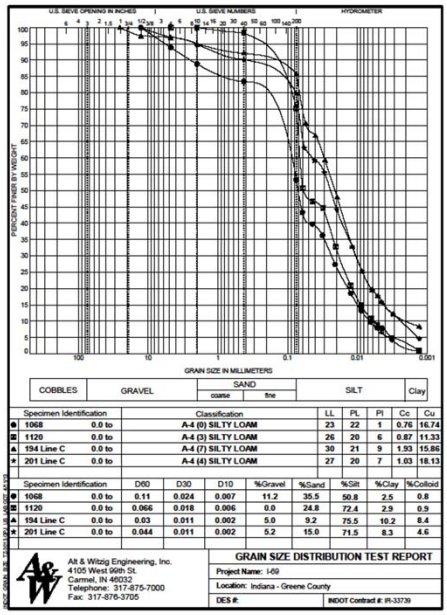


Chart 1 of 2



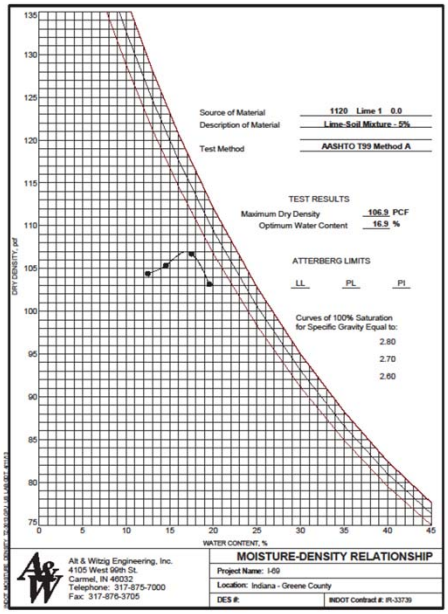
	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
◆	1068	0.0 to	A-4 (6) SILTY LOAM	23	22	1	0.76	16.74
■	1120	0.0 to	A-4 (3) SILTY LOAM	26	20	6	0.87	11.33
▲	194 Line C	0.0 to	A-4 (7) SILTY LOAM	30	21	9	1.93	15.86
*	201 Line C	0.0 to	A-4 (4) SILTY LOAM	27	20	7	1.03	18.13

	Specimen Identification		D60	D30	D10	%Gravel	%Sand	%Silt	%Clay	%Colloid
◆	1068	0.0 to	0.11	0.024	0.007	11.2	35.5	50.8	2.5	0.8
■	1120	0.0 to	0.066	0.018	0.006	0.0	24.8	72.4	2.9	0.9
▲	194 Line C	0.0 to	0.03	0.011	0.002	5.0	9.2	75.5	10.2	8.4
*	201 Line C	0.0 to	0.044	0.011	0.002	5.2	15.0	71.5	8.3	4.6

Alt & Witzig Engineering, Inc.
4105 West 99th St.
Carmel, IN 46032
Telephone: 317-875-7000
Fax: 317-876-3705

GRAIN SIZE DISTRIBUTION TEST REPORT

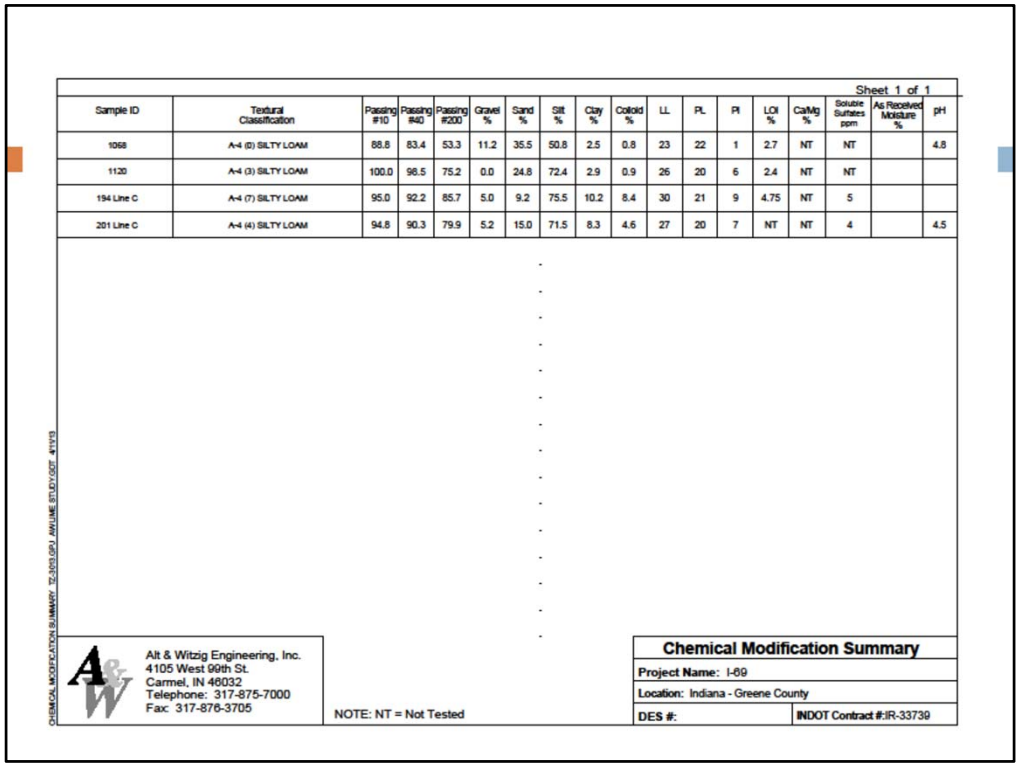
Project Name: I-69
Location: Indiana - Greene County
DES #:
INDOT Contract #: IR-33739



Alt & Witzig Engineering, Inc.
4105 West 99th St.
Carmel, IN 46032
Telephone: 317-875-7000
Fax: 317-876-3705

MOISTURE-DENSITY RELATIONSHIP

Project Name: I-69
Location: Indiana - Greene County
DES #:
INDOT Contract #: IR-33739



Sheet 1 of 1

Sample ID	Textural Classification	Passing #10	Passing #40	Passing #200	Gravel %	Sand %	Silt %	Clay %	Colloid %	LL	PL	PI	LOI %	Ca/Mg %	Soluble Sulfates ppm	As Received Moisture %	pH
1068	A-4 (0) SILTY LOAM	88.8	83.4	53.3	11.2	35.5	50.8	2.5	0.8	23	22	1	2.7	NT	NT		4.8
1120	A-4 (3) SILTY LOAM	100.0	98.5	75.2	0.0	24.8	72.4	2.9	0.9	26	20	6	2.4	NT	NT		
194 Line C	A-4 (7) SILTY LOAM	95.0	92.2	85.7	5.0	9.2	75.5	10.2	8.4	30	21	9	4.75	NT	5		
201 Line C	A-4 (4) SILTY LOAM	94.8	90.3	79.9	5.2	15.0	71.5	8.3	4.6	27	20	7	NT	NT	4		4.5

CHEMICAL MODIFICATION SUMMARY 12-2003.GPJ AWLUME.STD.V.GDT 4/1/13

Alt & Witzig Engineering, Inc.
4105 West 99th St.
Carmel, IN 46032
Telephone: 317-875-7000
Fax: 317-876-3705

NOTE: NT = Not Tested

Chemical Modification Summary

Project Name: I-69

Location: Indiana - Greene County

DES #:

INDOT Contract #: IR-33739

Soil Modification Mix Design

- Soil Classification Completed
  - Time to add the chemicals!
    - Lime product, Cement, or both?
  - Chemical selection depends on soil type
  - Moderately to Highly Plastic (A-7-6) (A-6)
    - Lime By-Product (LKD) or Quicklime (rare)
  - Low to Moderate Plasticity (A-6) (A-4)
    - Lime and/or Cement
  - Granular (A-4) (A-2-4) (A-1-a)
    - Cement

Soil Modification Mix Design

- Soil-Chemical Mixing and Testing
  - How much of each to start?
    - LKD 5% ($5 \pm 1\%$)
    - Cement 4% ($4 \pm 0.5\%$)
    - Organic and highly plastic soils may require additional percentages to be tested
  - Add the chemicals based on the dry weight of the soil
  - The soil - chemical mixture is then subjected to proctor testing to determine the MDD and OMC.

Comment on the shift in MDD and OMC

Soil Modification Mix Design

- Soil-Chemical MDD and OMC determined
  - Create strength specimens or "pills"
    - Compact mixture at ~95% MDD of T-99 effort
    - Mixture at OMC to +2%
  - Cure the specimens in plastic baggies in cure room at 100% humidity and ~73°F for 48 hrs
  - After cure, test in unconfined compression
  - Compare the average strength of two soil-chemical pills to an untreated soil pill to determine the "gain"

Mention that we also test "natural" pills

Soil Modification Mix Design

Specimen ID / Pill ID	Specimen Description				Strength Specimen Data					Minimum M.C. @ time of Compaction (%)
	LL	PL	PI	Fines	DD (pcf)	w%	% Comp.	PSI	PSI Gain	
1068 Cement	Cement-Soil Mixture - 4%				104.0	17.6	98.5	131	106	
1068 Lime 1	Lime-Soil Mixture - 5%				98.2	17.6	93.1	41	16	17.4
1068 Lime 2	Lime-Soil Mixture - 5%				98.5	17.7	93.4	39	14	
1068 Natural	A-4 (0) SILTY LOAM				103.4	15.8	98.0	25		
	23	22	1	53.3						
1120 Cement	Cement-Soil Mixture - 4%				100.4	17.4	93.9	137	113	
1120 Lime 1	Lime-Soil Mixture - 5%				97.7	17.8	91.4	35	11	16.9
1120 Lime 2	Lime-Soil Mixture - 5%				98.0	17.9	91.7	38	14	
1120 Natural	A-4 (3) SILTY LOAM				104.8	17.4	98.0	24		
	26	20	6	75.2						

Soil Modification Mix Design

- Current Strength Gain Requirements
  - Lime based chemicals
    - 50 psi
  - Cement
    - 100 psi

Soil Modification Mix Design

- Report Recommendations
  - If only one chemical meets the strength gain requirement…. that chemical is recommended.
  - If both chemicals are found to meet the requirements…
    - We generally lean toward lime (cost)
    - However, other non-laboratory parameters may dictate cement
  - If neither pass then it is likely that…
    - High plasticity, sugar sand, organics, waste materials
    - More testing would be required

Soil Modification Mix Design

- From the project we have been referencing:
- *"Recommendations*
-
- *We recommend 4% Portland Cement by dry weight be used for the soils at these locations. Chemically treated soils must be at or above the OMC as determined by the soil-chemical mixture. The soils-cement mixture should be at a minimum optimum moisture content of 17%."*

Soil Modification Mix Design

- Moisture-Water-H_20
  - Minimum moisture content prior to compaction
    - OMC to +2%
    - We must not leave the soil-chemical mixture thirsty!
  - Compacting soil-chemical mixture below OMC
    - Higher air voids
    - Incomplete chemical reaction
    - Potential for catastrophic subgrade failures

Soil Modification Mix Design

- Other Considerations
  - The laboratory testing is limited to the laboratory!
  - Consider all aspects of the project
    - Foundation Soils - are they stable?
      - Largest majority of subgrade modification "failures" are due to weak foundation soils
      - Must be treated before attempting subgrade modification
    - When will the work take place?
    - What worked on the previous section?

Soil Modification Mix Design

- How long will it take?
  - Typical projects can be completed in 2-3 weeks
  - Larger projects with more samples or troublesome soils will take longer
  - Our lab completes over 100 studies a year
  - Get the samples as early as possible!
    - Technically, the results need to be in the hands of the INDOT Engineer 5 days prior to field operations

Soil Modification Mix Design

- In Summary
  - Steps to initiate the mix design
  - Sampling locations & number
  - Laboratory testing requirements
  - Recommendations of the report
  - Time frame for the study

  - Thank you, hold the questions please!